

CLAIMS

What is claimed is:

1           1.    A method of operating a camless engine valve  
2    actuation system in an internal combustion engine, the system  
3    including one or more actuators controlled by a controller  
4    operating under program control to control an engine valve,  
5    comprising:

6           determining a safe trajectory for the engine valve  
7    versus crankshaft angle, the safe trajectory separating  
8    acceptable trajectories from unacceptable trajectories  
9    risking or causing collision of the engine valve another  
10   engine valve or with the engine piston;

11          determining the desired trajectory for the engine valve  
12   versus crank angle;

13          controlling the actuators to nominally cause the engine  
14   valve to follow the desired trajectory;

15          sensing the actual engine valve trajectory, and if the  
16   actual engine valve trajectory deviates into an unacceptable  
17   trajectory, controlling the actuators to close the engine  
18   valve.

1           2.    The method of claim 1 further comprising, if the  
2    actual engine valve trajectory deviates from the desired  
3    trajectory more than an allowable deviation within the

4 acceptable trajectories, controlling to actuators to reduce  
5 the deviation.

1       3.    The method of claim 1 wherein the desired  
2 trajectory for the engine valve versus crank angle is  
3 determined as a desired opening angle, a desired opening  
4 flank rate, a desired lift, a desired closing flank rate and  
5 a desired closing angle.

1       4.    The method of claim 1 wherein the control of the  
2 actuators to nominally cause the engine valve to follow the  
3 desired trajectory is based in part on previous actuator  
4 controls and associated engine valve responses.

1       5.    The method of claim 1 wherein the safe trajectory  
2 for an intake valve is comprised of a minimum opening angle  
3 and a maximum allowable opening flank rate.

1       6.    The method of claim 1 wherein the safe trajectory  
2 for an exhaust valve is comprised of a maximum allowable  
3 closing angle and a minimum allowable closing flank rate.

1       7.    The method of claim 1 wherein the safe trajectory  
2 for an exhaust valve is comprised of a minimum allowable  
3 opening angle and a maximum allowable opening flank rate.

1        8.    The method of claim 1 wherein a safe trajectory is  
2    determined based on engine operating conditions and  
3    environmental conditions.

1        9.    The method of claim 8 wherein a safe trajectory is  
2    determined based on past, current and commanded engine load.

1        10.   The method of claim 1 wherein a desired trajectory  
2    is determined based on engine operating conditions and  
3    environmental conditions.

1        11.   The method of claim 10 wherein a desired trajectory  
2    is determined based on past, current and commanded engine  
3    load.

1        12.   The method of claim 10 wherein the desired  
2    trajectory for the engine valve is determined, at least in  
3    part, from equations.

1        13.   The method of claim 10 wherein the desired  
2    trajectory for the engine valve is determined, at least in  
3    part, from lookup tables.

1        14.   The method of claim 1 wherein the safe trajectory  
2    for the engine valve is determined, at least in part, from  
3    equations.

1        15. The method of claim 1 wherein the safe trajectory  
2 for the engine valve is determined, at least in part, from  
3 lookup tables.

1        16. The method of claim 1 wherein the actuators  
2 comprise a hydraulic actuator controlled by electronically  
3 controlled valving.

1        17. The method of claim 16 wherein the hydraulic  
2 actuator is a single stage hydraulic actuator.

1        18. The method of claim 17 wherein the hydraulic  
2 actuator is a two stage hydraulic actuator.

1        19. The method of claim 18 wherein a first stage  
2 comprises electromagnetically actuated spool valving, and the  
3 second state comprises hydraulically controlled spool  
4 valving.

1        20. A method of operating a camless engine valve  
2 actuation system in an internal combustion engine, the system  
3 including one or more actuators controlled by a controller  
4 operating under program control to control an engine valve,  
5 comprising:

6        determining a safe trajectory for the engine valve  
7 versus crankshaft angle, the safe trajectory separating

8 acceptable trajectories from unacceptable trajectories  
9 risking or causing collision of the engine valve with another  
10 engine valve or with the engine piston;  
11 determining the desired trajectory for the engine valve  
12 versus crank angle;  
13 controlling the actuators to nominally cause the engine  
14 valve to follow the desired trajectory;  
15 sensing the actual engine valve trajectory, and;  
16 if the actual engine valve trajectory deviates from the  
17 desired trajectory by more than an allowable deviation,  
18 controlling to actuators to reduce the deviation;  
19 if the actual engine valve trajectory deviates from the  
20 desired trajectory into an unacceptable trajectory,  
21 controlling the actuators to close the engine valve.

1 21. The method of claim 20 wherein the desired  
2 trajectory for the engine valve versus crank angle is  
3 determined as a desired opening angle, a desired opening  
4 flank rate, a desired lift, a desired closing flank rate and  
5 a desired closing angle.

1 22. The method of claim 20 wherein the control of the  
2 actuators to nominally cause the engine valve to follow the  
3 desired trajectory is based in part on previous actuator  
4 controls and associated engine valve responses.

1        23. The method of claim 20 wherein the safe trajectory  
2 for an intake valve is comprised of a minimum opening angle  
3 and a maximum allowable opening flank rate.

1        24. The method of claim 20 wherein the safe trajectory  
2 for an exhaust valve is comprised of a maximum allowable  
3 closing angle and a minimum allowable closing flank rate.

1        25. The method of claim 20 wherein the safe trajectory  
2 for an exhaust valve is comprised of a minimum allowable  
3 opening angle and a maximum allowable opening flank rate.

1        26. The method of claim 20 wherein a safe trajectory is  
2 determined based on engine operating conditions and  
3 environmental conditions.

1        27. The method of claim 26 wherein a safe trajectory is  
2 determined based on past, current and commanded engine load.

1        28. The method of claim 20 wherein a desired trajectory  
2 is determined based on engine operating conditions and  
3 environmental conditions.

1        29. The method of claim 28 wherein a desired trajectory  
2 is determined based on past, current and commanded engine  
3 load.

1           30. The method of claim 28 wherein the desired  
2 trajectory for the engine valve is determined, at least in  
3 part, from equations.

1           31. The method of claim 28 wherein the desired  
2 trajectory for the engine valve is determined, at least in  
3 part, from lookup tables.

1           32. The method of claim 20 wherein the safe trajectory  
2 for the engine valve is determined, at least in part, from  
3 equations.

1           33. The method of claim 20 wherein the safe trajectory  
2 for the engine valve is determined, at least in part, from  
3 lookup tables.

1           34. The method of claim 20 wherein the actuators  
2 comprise a hydraulic actuator controlled by electronically  
3 controlled valving.

1           35. The method of claim 34 wherein the hydraulic  
2 actuator is a two stage hydraulic actuator.

1           36. The method of claim 35 wherein a first stage  
2 comprises electromagnetically actuated spool valving, and the  
3 second state comprises hydraulically controlled spool  
4 valving.